Contaminated Sediments

Confounding Factors (CF)
In Toxicology

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Introduction

- Purpose: RPMs will leave this session understanding that...
  - Confounding Factors (CFs) are sediment features that cause toxicity, but they are not COPECs
  - CFs create unnecessary costs to sediment remediation programs
  - CFs can be addressed in an acceptable regulatory framework

Introduction (cont.)

- RPMs will also leave understanding that...
  - Sediment chemistry can exceed accepted ARARs without having an unacceptable adverse biological effect – BIOAVAILABILITY ISSUE
  - Unacceptable adverse biological effects can occur that are not related to COPECs – CF ISSUE
  - Appropriately conducted bioassays are a good thing

COPEC To COC = Risk Assessment

- Historical review
- Screening process
- Acute toxicity testing
- Bioaccumulation testing

COPEC To COC = Risk Assessment

HISTORICAL REVIEW:

- COPECs are identified through evaluation of past history at a site

COPEC To COC = Risk Assessment

SCREENING PROCESS:

- Comparison to Benchmark Sediment Criteria or Advisory Concentrations

COPEC To COC = Risk Assessment

ACUTE TOXICITY TESTING:

- COPECs become COCs if an unacceptable adverse biological effect occurs **as a result** of exposure to the COPEC at greater than trace quantity

COPEC To COC = Risk Assessment

BIOACCUMULATION TESTING

- Bioaccumulation evaluation addresses bioavailability
- Relative Absorption Factor (RAF) < 1

Confounding Factors?

- CFs Interfere with the Evaluation of COPEC TO COC
  - CFs are sediment factors that produce unacceptable conditions for test organisms, but are not:
    - chemicals of concern
    - factors that control legal decisions

Topics of Discussion

- Value Added by Addressing CFs
  - Oakland example of added value
- Regulatory Stance for Addressing CFs
- Types of CFs
  - Ammonia example
- How to Successfully Address CF Issues
  - Questions RPMs can ask
  - Critical steps to addressing CFs with agencies

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- Value Added by Addressing CFs

Value Added by Addressing CFs

- Provide examples of chemical-specific sediment ARARs
  - Cleanup goals: Match these ARARs
- Oakland example
  - Screening factor definitions and relationships to ARARs
  - Decisions on screening factors from CF and bioavailability assessments

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– Oakland example of added value

Oakland Example of Added Value
ARAR List

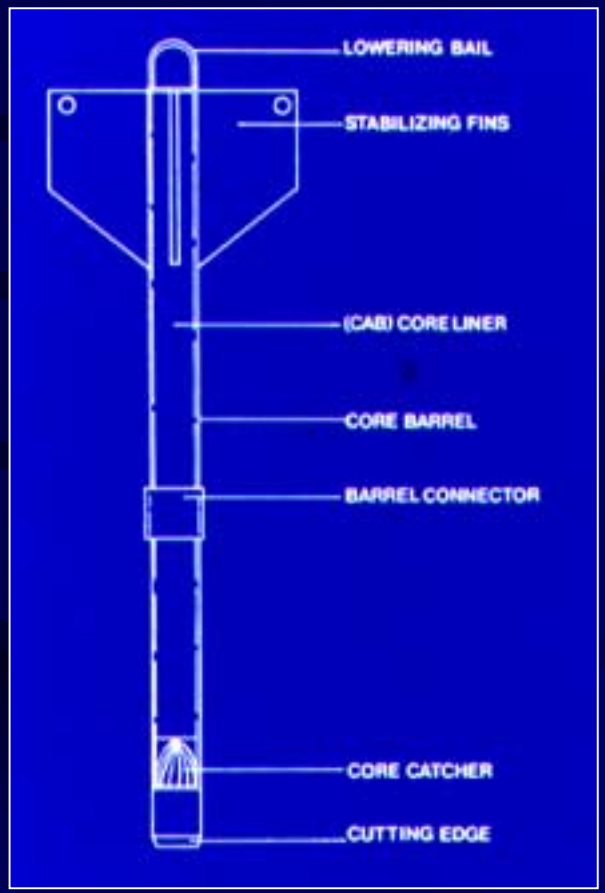
- ERL, ERM, MS/OBM Reference Screening Values, AET, Wetland Concentrations for Non-Cover and Cover, Reference Area Wetland Screening Values
  - All values used during Oakland evaluation were **demonstrated** to be protective of the environment

Oakland Example of Added Value

- Oakland Background
  - 50-ft deepening project
    - same as San Diego carrier deepening project
  - 14 to 20 million cubic yard program
  - Potential beneficial use

Oakland Example
Alternative Sampling Equipment

Oakland Example
Alternative Sampling Equipment



Oakland Example of Added Value

Oakland Example of Added Value

- Screening Factors (SFs) and Expected Sediment Volumes
  - SF1 4 core comp/200,000 cy 9.0 M cy
  - SF2 4 core comp/100,000 cy 5.1 M cy
  - SF3 4 core comp/50,000 cy 0.3 M cy

Oakland Example of Added Value

- Expected Conditions of Sediment with SF1 Characteristics
  - SF1 WILL exceed ERM screening criteria; and WILL have elevated mortality due to sediment compactness, low water content, low organic carbon content, CFs, and little to no bioaccumulation of COCs

Oakland Example of Added Value

- Expected Conditions of Sediment with SF2 Characteristics
  - SF2 MAY exceed ERM screening criteria; MAY have elevated mortality due to CF or COCs; MAY have CF associated with poor organic carbon, ammonia, sulfides; and MAY have bioaccumulation of COCs

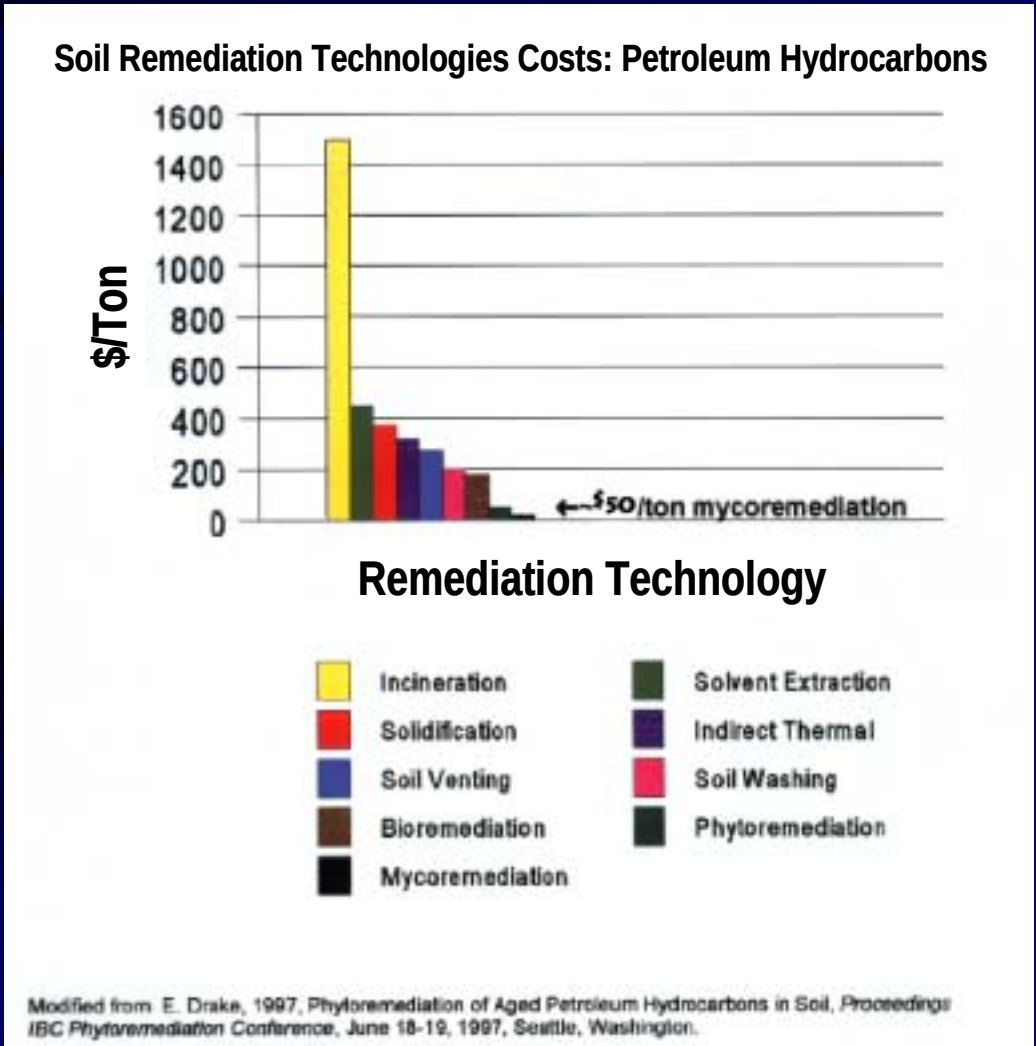
Oakland Example of Added Value

- Expected Conditions of Sediment with SF3 Characteristics
  - SF3 WILL exceed ERM screening criteria; and WILL have elevated mortality due to CF and COCs. MAY have CF associated with poor organic carbon, ammonia, sulfides. LIKELY to bioaccumulate COCs

Oakland Example of Added Value

- Projected Outcome of Decisions by Resource Agencies Without CF Being Adddressed
  - SF1 sediment rejected due to exceedences of ERM values and unexplained mortality resulting from lack of food and compact sediment (9.0 M cy)
  - SF2 sediment rejected due to exceedences of ERM values and mortality resulting from CF of ammonia, sulfide and TOC quality in addition to COCs (5.1 M cy)
  - SF3 sediment rejected due to all factors (0.3 M cy)

Oakland Example of Added Value
Relative Cost of Treating Soils/Cubic Yard



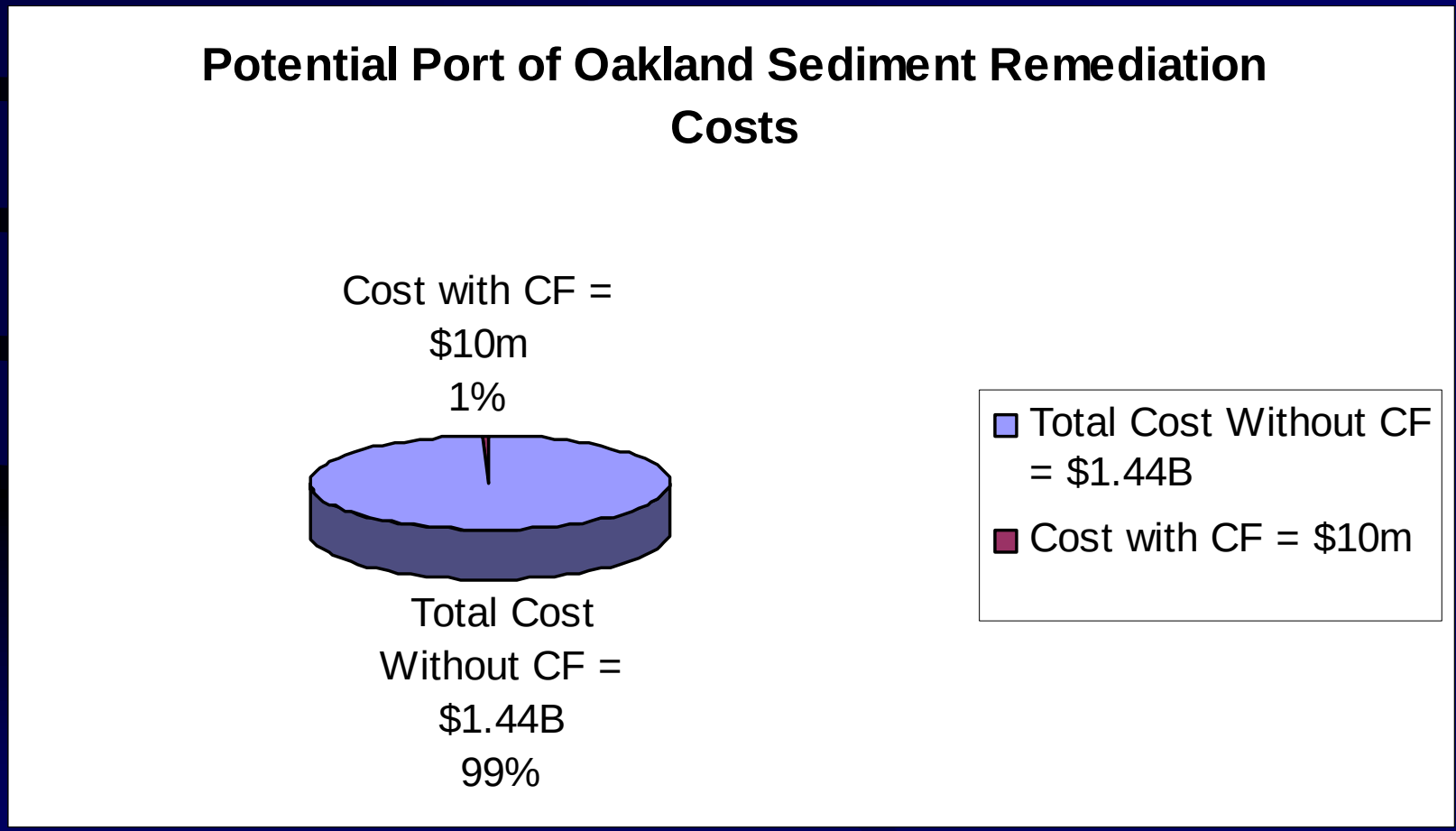
Oakland Example of Added Value

Relative Cost of Treating Soils After Addressing CF with Agencies

- Cost of sediment treatment assuming same procedure applied to all sites without CFs being addressed
  - 14.4M cy * $100/cy = $1.44B
- Cost of sediment handling assuming procedure applied to all sites after CFs were addressed
  - 0.1M cy * $100/cy = $10M. Or <0.1% of potential cost

Oakland Example of Added Value

Relative Cost of Treating Soils After Addressing CF with Agencies



Oakland Example of Added Value

- Results of the Application of Methods to Address CFs
  - Project moved forward
  - Agencies backed decisions and supported solutions
  - Reduction in costs to complete project because only unacceptable biological effects due to persistent COCs at greater than trace quantities controlled decisions

Topics of Discussion

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- Types of CFs
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  - Questions RPMs can ask
  - Critical steps to addressing CFs with agencies

- Regulatory Stance for Addressing CFs

Regulatory Stance for Addressing CFs

- List of laws
- CFs are those sediment features which are
  - Not COPCs
  - Not at higher than trace concentrations
  - Not persistent

Regulatory Stance for Addressing CFs
Effectiveness Of Toxicity Testing

Toxicity testing has been highly successful in the past, resulting in numerous laws and procedures for evaluating toxicity.

- Rivers and Harbors Act (1899)
- Oslo Convention (1972)
- London Dumping Convention (1975)
- Bonn Agreement (1969)
- Marpol Convention (1973/1978)
- Clean Water Act
- Federal Water Pollution Control Act
- Water Quality Act
- Toxic Substances Control Act (TSCA) (1976)
- Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) (1975)
- The Marine Protection, Resources, and Sanctuaries Acts (MPRSA) (1972)
- Comprehensive Environmental Response, Compensation, and Liability Act/Superfund Amendments and Reauthorization Act (CERCLA/SARA)
- Resources Conservation and Recovery Act (RCRA)
- National Environmental Policy Act (1969)
- Environmental Quality Improvement Act (EQIA) (1970)

Regulatory Stance for Addressing CFs
Appropriate Toxicology Tests

- Laws agree that they are designed to protect the environment from unacceptable adverse impacts of persistent, chemical contaminants of concern at greater than trace quantities
  - Persistent
  - Chemical contaminants of concern
  - Trace
- Biological tests override chemical-based criteria

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■ Types of CFs

Types of Confounding Factors

- Non-Persistent Contaminants
  - Ammonia
  - Salinity
  - Sulfides
  - Organic carbon quality
  - Water hardness/alkalinity
  - pH
  - Temperature
  - Suspended solids

Types of Confounding Factors

- Persistent Sediment Features
  - Sediment grain size
  - Total organic carbon quantity
  - Heavy metals associated with mineral fraction of the sediment
  - Sediment compactness
  - Sediment water content

Types of Confounding Factors

- Laboratory Differences
  - Interpopulation sensitivity
  - Interlaboratory comparisons
  - Intralaboratory comparisons

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- Ammonia example

Ammonia Example

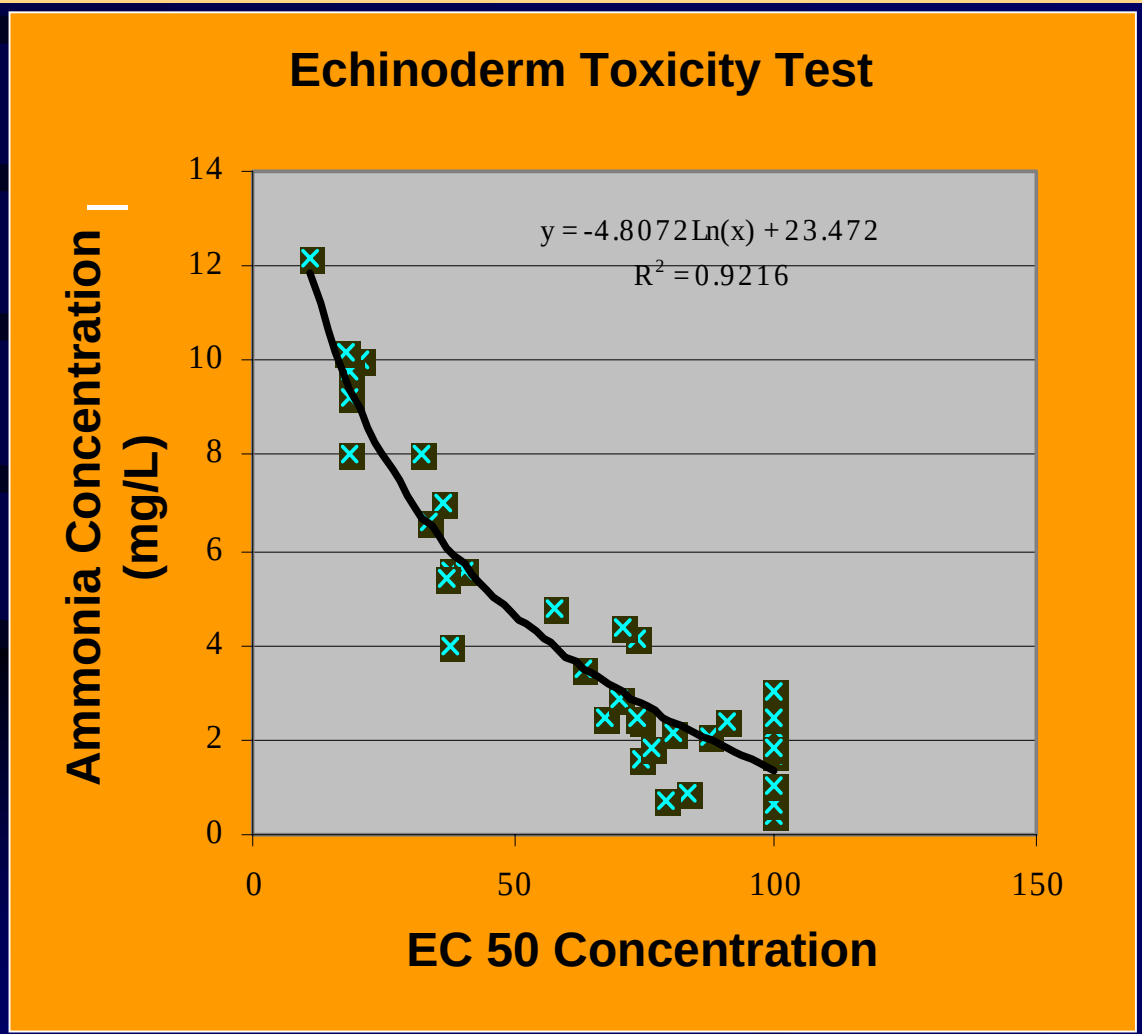
AMMONIA – non-persistent CF
Where has it been a problem?

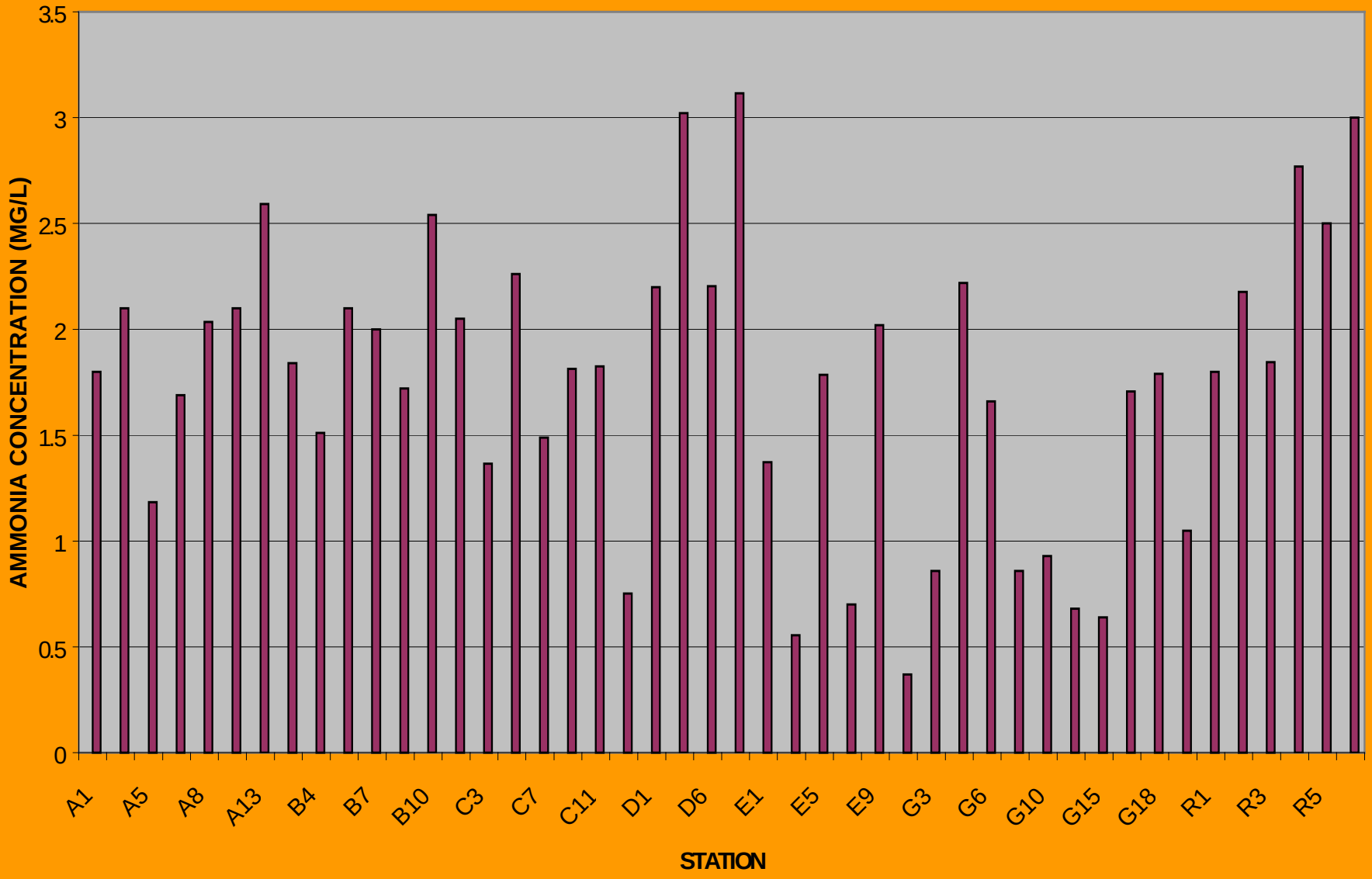
- San Francisco Bay, California
  - Oakland and Richmond Harbors
  - John F. Baldwin Ship Channel
  - Mare Island Straits
  - San Raphael – across the flats
  - Treasure Island
- New York Harbor
- Charleston, South Carolina
- Puget Sound, Washington
- Aquarium Stores

Ammonia Example

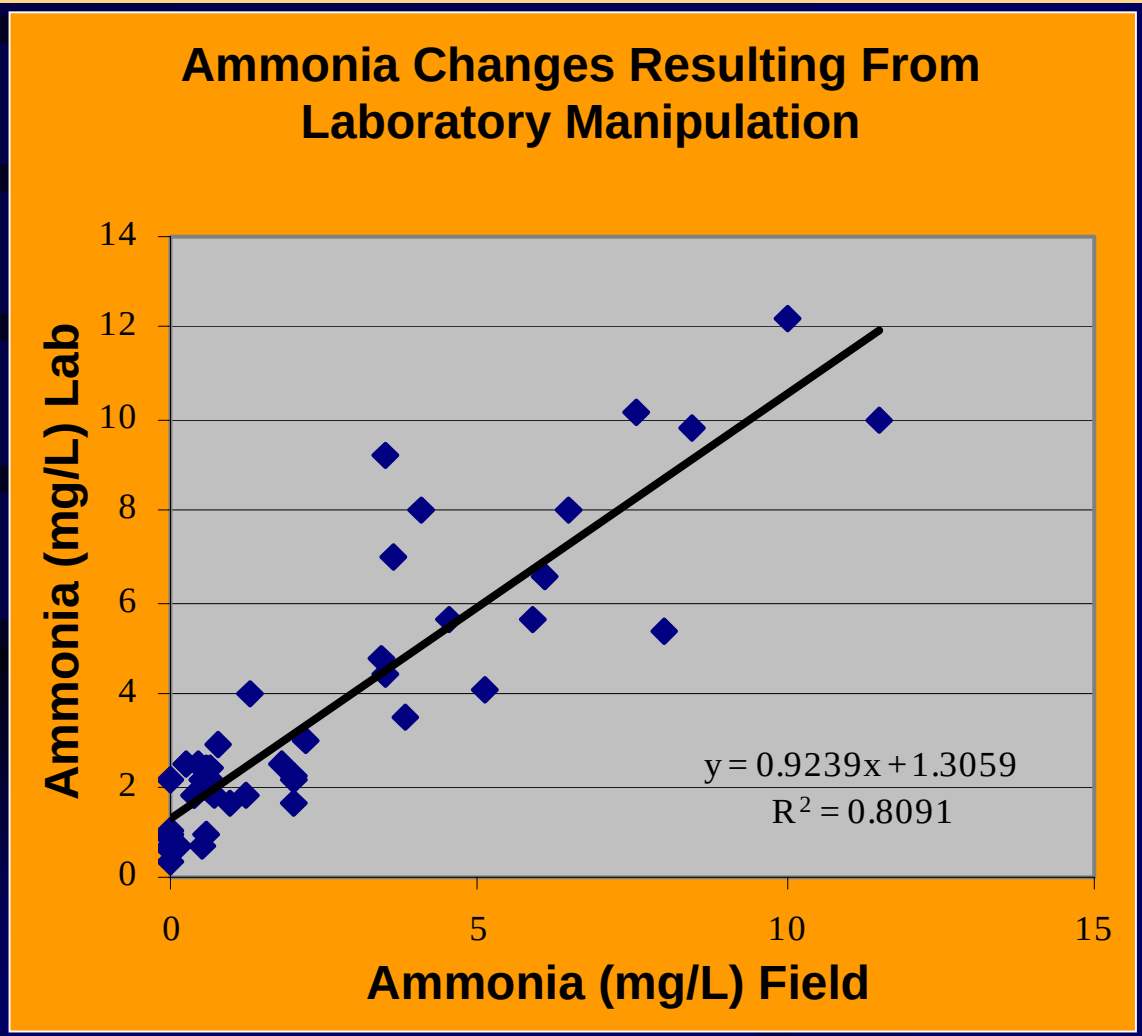
- Tropical fish stores face similar problems with ammonia
- If a tropical fish store handled their **expensive** fish the way we do toxicity testing they would go out of business
- Don’t we owe it to our programs to be at least as careful with our bioassays, whose results control millions of dollars worth of sediment remediation costs?

Ammonia Example




EC50 CONCENTRATIONS
AMMONIA CONCENTRATION (MG/L)
3.5
3
2.5
2
1.5
1
0.5
0
A1
A5
A8
A13
B4
B7
B10
C3
C7
C11
D1
D6
E1
E5
E9
G3
G6
G10
G15
G18
R1
R3
R5
STATION

Ammonia Example



Ammonia Example
What This Means

- The tropical fish store had an obvious answer. Address the issue of the non-persistent CF, ammonia, or go out of business.
- The examples of ammonia and other CFs being addressed indicated a savings of >99% in Oakland Harbor
- The examples of CFs at Treasure Island indicated that they were created by laboratory artifact

Topics of Discussion

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  - Questions RPMs can ask
  - Critical steps to addressing CFs with agencies

- How to Successfully Address CF Issues

How to Successfully Address CF Issues

- Ask yourselves the questions that follow.
- Follow the critical steps for successfully addressing CF issues with regulatory agencies.

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- Questions RPMs can ask

How to Successfully Address CF Issues
Questions RPMs Can Ask

- Is the sediment in an area of freshwater influence?
- Is a source of recent organic enrichment present?
- Is the assessment addressing sediment that is buried deeper than 10 cm?
- Is the assessment addressing older and more compact sediment?
- What is the sediment grain size?
- Are there sharp angles on sediment grains?
- Is the heavy metal content of the sediment determined by a complete digestion method?
- Is the assessment evaluating COCs in place?
- Is the assessment evaluating the effects of COCs during removal?
- Is the assessment evaluating COCs during disposal or placement of sediment at another site?
- What was the survival of the test organisms prior to conduct of the test?
- What test conditions were applied to the test?
- Who provided test organisms?
- What was the acclimation schedule for the test organisms prior to test?

How to Successfully Address CF Issues
Questions RPMs Can Ask

- Is the sediment in an area of freshwater influence?
  - If so, the CFs influencing organism survival are:
    - Low salinity
    - Increased ammonia with longer tests being more influenced

How to Successfully Address CF Issues
Questions RPMs Can Ask

- Is a source of recent organic enrichment present?
  - If yes, then the CFs to address are:
    - Total organic carbon quantity
    - Total organic carbon quality
    - Ammonia and sulfide toxicity
  - If no, then the CFs to address are:
    - Lack of food quantity and/or quality

How to Successfully Address CF Issues
Questions RPMs Can Ask

- Is the assessment addressing sediment that is buried deeper than 10 cm?
  - If yes, then the CFs to address are:
    - Ammonia and sulfide toxicity as well as sediment compactness and water content
  - If no, then the CF's to address are:
    - Potential predators in unsieved sediment samples

How to Successfully Address CF Issues
Questions RPMs Can Ask

- Is the assessment addressing older and more compact sediment?
  - If yes, then the CFs to assess are:
    - Ability of test organisms to burrow into sediment
    - Lack of water in compacted sediment
    - Lack of quality organic material
    - Potential ammonia or sulfide issues

How to Successfully Address CF Issues
Questions RPMs Can Ask

- What is the sediment grain size?
  - The CF that should be addressed here is:
    - Is the grain size appropriate for the test species?
    - Can the influence of grain size on toxicity be accounted for?

How to Successfully Address CF Issues
Questions RPMs Can Ask

- Are there sharp angles on sediment grains?
  - If yes, the CF that needs to be addressed is:
    - Injury to soft tissue organisms that burrow through sediment-select species that are composed of harder exoskeletons or which do not burrow through sediment

How to Successfully Address CF Issues
Questions RPMs Can Ask

- Is the heavy metal content of the sediment determined by a complete digestion method?
  - If yes, the CF to address is the bioavailability of the metals in the sediment sample

How to Successfully Address CF Issues
Questions RPMs Can Ask

- Is the assessment evaluating COCs in place?
  - If yes, the CF that needs to be addressed is:
    - Species selection – the species should be a good surrogate for species that live in the vicinity of the sediment. Do not match the sediment to the species, match the species to the environmental types

How to Successfully Address CF Issues
Questions RPMs Can Ask

- Is the assessment evaluating the effects of COCs during removal?
  - If yes, the CF that needs to be addressed is:
    - Species selection – is the species a good and appropriate surrogate species for the environmental conditions at the removal site? Match the species selection to the environmental conditions at the site

How to Successfully Address CF Issues
Questions RPMs Can Ask

- Is the assessment evaluating COCs during disposal or placement of sediment at another site?
  - If yes, the CF that needs to be addressed is:
    - Species selection – is the species a good and appropriate surrogate species for the environmental conditions at the disposal site? Match the species selection to the environmental conditions at the site

How to Successfully Address CF Issues
Questions RPMs Can Ask

- What was the survival of the test organisms prior to conduct of the test?
  - If the survival of the test organisms prior to the test was low, then the test organisms are likely to be too sensitive and excess toxicity will result

How to Successfully Address CF Issues
Questions RPMs Can Ask

- What test conditions were applied to the test?
  - If the organisms were tested in conditions outside of their normal use then they will be more sensitive and have higher mortality

How to Successfully Address CF Issues
Questions RPMs Can Ask

- Who provided test organisms?
  - The CFs associated with this question are:
    - Handling issues and increased sensitivity
    - Population sensitivity differences within the same species but collected from different areas

How to Successfully Address CF Issues
Questions RPMs Can Ask

- What was the acclimation schedule for the test organisms prior to test?
  - Too abrupt changes in water conditions can increase sensitivity of test populations

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Critical Steps to Addressing CFs with Agencies

- There are successful procedures for addressing CF issues with agency personnel

Critical Steps to Addressing CFs with Agencies

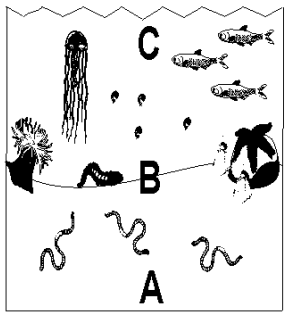
- **Determine** the specific question that is being addressed
- **Identify** the most likely CFs
- **Before** sampling occurs, address the methods for assessment of CF influences
- **Develop** sampling and analysis plans to address CFs with agency participation

Critical Steps to Addressing CFs with Agencies

- **Obtain** interpretation framework agreement with agencies
- **Perform** tests, **follow** interpretation framework guidelines, and **present** results to resource agencies
- **Do not try and explain away CF influences without site-specific supporting studies**

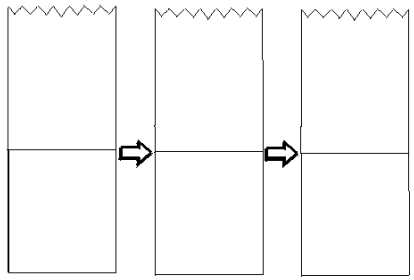
Contaminant Availability Factors

Organism Exposure



Sediment Disturbance

Increases Bioavailability



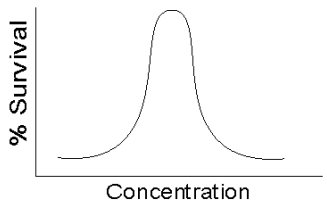
Increasing Disturbance

Storage

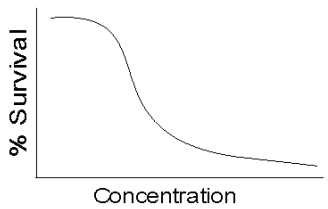
Alters Bioavailability

Confounding Factors

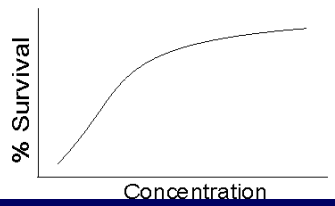
S°/₀₀
TOC Quantity
Grain Size



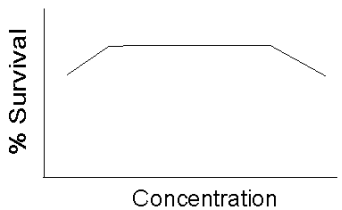
NH_3 : Sulfide



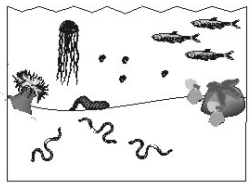
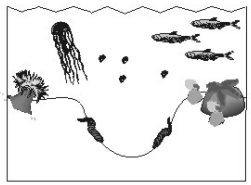
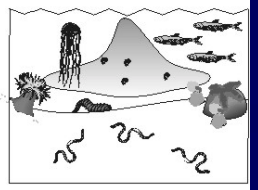
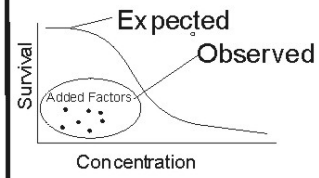
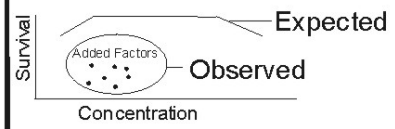
TOC - Quality



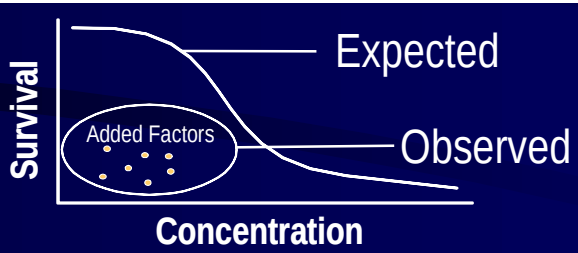
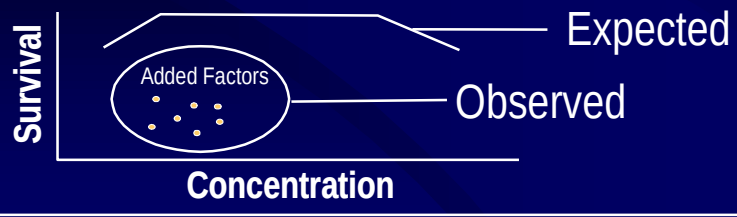
Grain Size



Testing Options to Account for Factors Under 3 Assessment Types

Contaminant Availability Factors	In-Situ	Removal	Disposal
Organism Exposure			
Sediment Disturbance	Minimize	Maximize	Maximize
Storage	Minimize	Minimize	Minimize
Confounding Factors			
S°/°° TOC Quantity Grain Size	Select Species whose Tolerances Match **In-Situ Conditions**	Select Species whose Tolerances Match **Conditions of Removal Site**	Select Species whose Tolerances Match **Disposal Environment**
NH_3 : Sulfide	 Overlying Water Exchange or Wait	***OR*** Disturbance Acceptable	Disturbance Acceptable
TOC - Quality	Assess Potential for Factor to Influence Test Results (Quantity / Quality Synergism)		
Grain Size			

Testing Options to Account for Factors Under Three Assessment Types

	In Situ	Removal	Disposal
S% TOC Quantity Grain Size	Select species whose tolerances match **In Situ Conditions**	Select species whose tolerances match **Conditions of Removal Site**	Select species whose tolerances match **Disposal Environment**
NH_3: Sulfide	 Overlying Water Exchange or Wait	Disturbance Acceptable	***OR*** Disturbance Acceptable
TOC – Quality	Assess potential for factor to influence test results (Quantity/Quality Synergism)		
Grain Size			

Conclusions

- Sediment has been classified as toxic due to CFs. **This is an expensive and inappropriate answer and would bankrupt a normal business.**
- Sediment that has COCs greater than guidance values but with little bioavailability can be classified as an acceptable risk through **appropriately conducted** toxicity tests. (***Biological overrides to sediment screening values***)

Conclusions

- Agency personnel will accept results of CF and bioavailability evaluations
- Agency personnel will appropriately classify sediment as acceptable
- **Remember the Oakland example**. Costs for remediation were reduced to less than 1% of the potential costs after CFs were addressed.

References

- Drake, E. 1997. "Phytoremediation of Aged Petroleum Hydrocarbons in Soil." *Proceedings of the IBC Phytoremediation Conference, June 18-19, 1997.* Seattle, WA.
- NRC. 1997. *Contaminated Sediments in Ports and Waterways.* National Research Council, Washington,DC.

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Or

- Your Local TSR